Is there spectral variation in the polarized reflectance of leaves?

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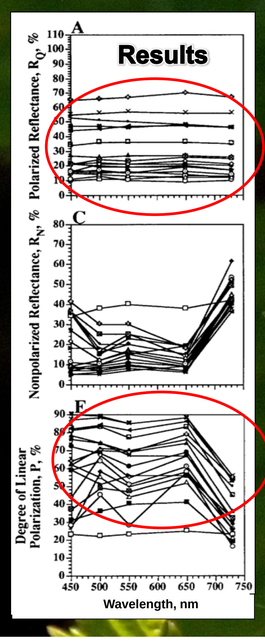
Introduction: Our prior research

concluded

There is no spectral information in the polarized portion of the bidirectional reflectance factor BRF(55˚,0˚;55˚,180˚) of healthy green leaves in the 400-800nm wavelength region.

Physiologia Plantarum 88:1-9, 1993.



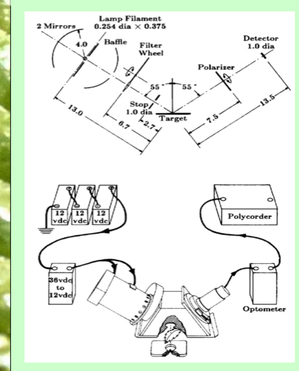
Leaf polarized reflectance is spectrally ***flat*** !!!

Note that degree of linear polarization does vary with wavelength

Plant species measured

- *Abutilon theoprahsti*
- *Acer saccharum*, common
- *Acer saccharum*, Indiana
- *Asclepias syriaca*
- *Caladium bicolor*
- *Chenopodium album*
- *Cucurbita pepo*
- *Glycine max*
- *Gynura aurantiaca*
- *Helianthus annuus*
- *Lycopersicon esculentum*
- *Quercus borealis*
- *Quercus prinus*
- *Quercus velutina*
- *Solanum pycanthum*
- *Sorghum bicolor*
- *Ulmus americana*
- *Zea mays*

Spectrometer measured leaf *in situ*



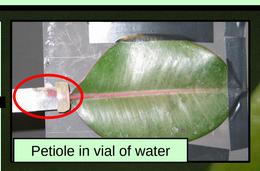
This research

asked the question

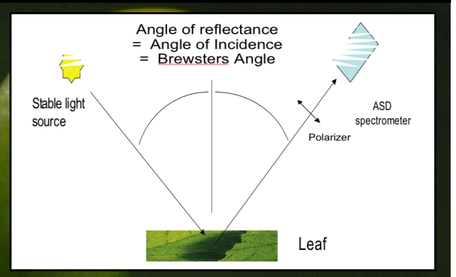
Is there hyperspectral information in the polarized portion of the bidirectional reflectance factor BRF(55˚,0˚;55˚,180˚) of healthy green leaves in the 500-2500nm wavelength region?

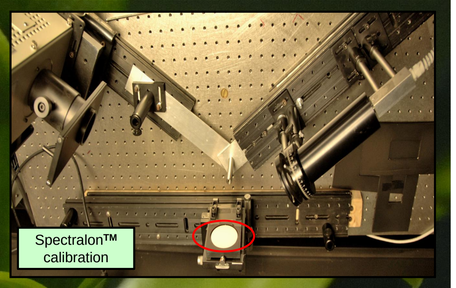
Approach

- Measure detached leaves
  - cannabis
  - coffee
  - ficus
  - philodendron
  - spathiphyllum
- Leaf petioles in vials of water
- Incidence = Reflection = 55˚
- Approximately Brewsters angle
- ASD FieldSpec Pro Spectroradiometer
- 1˚ fore optic
- Wire grid polarizer 500-2400nm
- Calibration with Spectralon™ surface



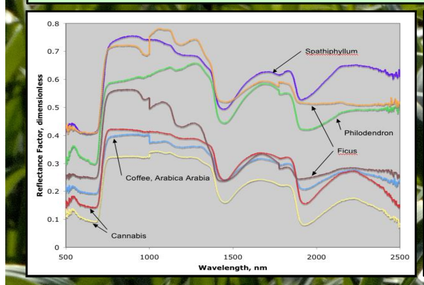
Petiole in vial of water



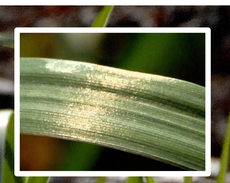


Spectralon™ calibration

Results

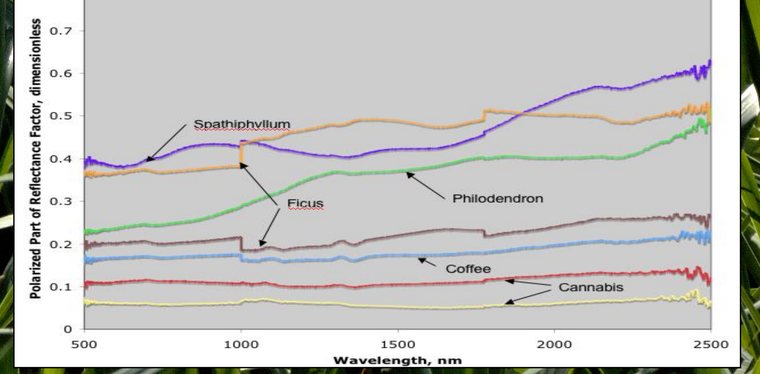


Bidirectional Reflectance Factor (BRF) spectra are typical of green leaves – green peak at 550nm, red minimum around 650-680nm, red edge between 700-720nm, near infrared plateau between 760 and 1100nm, large water absorption bands at 1,450 and 1,940nm.



Results

- Polarized BRF spectra (below) of green leaves appear reasonably flat – and, unlike the BRF spectra (Results upper-left), display no peak in the green wavelength region, minimum in the red, a red edge, maximum in the near infrared, nor evidence of water absorption bands at 1450 and 1940nm.
- 5 of 7 polarized BRF spectra generally increase between 500 and 2,500nm wavelength.
- Polarized BRFs of ficus and spathiphyllum cross over:
  ficus > spathiphyllum for 1050nm < λ < 1900nm and
  ficus < spathiphyllum for λ < 1050nm and λ > 1900nm
- Derivatives (i.e. slopes) of polarized BRF spectra vary with wavelength from negative to near zero to positive.



Conclusions

- No hyperspectral variation in the polarized BRF of leaves of five plant species measured 500-2500nm
- No evidence chlorophyll or water absorbed polarized light, because measured spectra are flat.
- Results support hypothesis that light from leaf is polarized during first surface, quasi specular reflection. Polarized light never entered leaf to interact with pigments and water.
- We use ”quasi specular,” because electron micrographs reveal that on all leaves an amorphous wax surface supports particles and structures – leaf surface is not optically smooth.
- General increase in the polarized BRF from 500 to 2500nm wavelength is due to leaf surfaces better approximating optically smooth surface at 2500nm than at 500nm.
- More data needed to assess if polarized BRF cross-overs and slope changes are typical of polarized spectra or represent measurement noise.
- Degree of linear polarization (DOLP) (polarized BRF divided by BRF) varies dramatically with wavelength only because BRF varies dramatically with wavelength.